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WEAPON SYSTEM 133B.(U)
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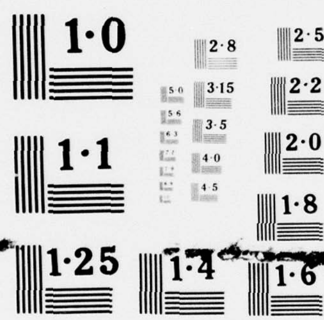

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WEAPON SYSTEM 133B

FINAL REPORT

FLIGHT-TEST FIRING OF SECOND-STAGE WING VI MINUTEMAN MOTOR STM-14W-1 (52PQA6-83)

Contract F04704-75-C-0038

Report 0162-02TR-STM-14W-1 10 August 1977

aerojet solid propulsion company
P. O. BOX 13400 SACRAMENTO, CALIFORNIA 95813 • A DIVISION OF AEROJET-GENERAL

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WEAPONS SYSTEM 133B

FINAL REPORT

FLIGHT-TEST FIRING OF SECOND-STAGE WING VI
MINUTEMAN MOTOR STM-14W-1 (52PQA6-83)

9 Final rept.

Contract F04704-75-C-0038

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Prepared for:

Space and Missile Systems Organization
Air Force Systems Command, USAF
Norton Air Force Base, California

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FIGURE LIST

I. SUMMARY

Minuteman III Special Test Missile 14W-1, with Aerojet-supplied Second Stage Motor AA21517 (PQA6-83), was successfully fired from the Western Test Range (WTR) on 16 June 1977. The missile was tested from Launch Facility 21; range zero time was approximately 1900 hr P.d.t. (0200:00.817 hr UTC). Performance of the second stage motor was satisfactory and all measured performance parameters were within model specification limits.

The motor ignited satisfactorily and operated for an action time of 65.2 sec. Second stage skirt jettison occurred 16.40 sec after Stage I-II staging.

The liquid injection thrust vector control and roll control system performed satisfactorily. Injectant utilization was 101.2 lb.

II. TEST OBJECTIVES AND MOTOR DESCRIPTION

A. TEST OBJECTIVE

The primary objective of the flight test is classified; a secondary objective was to demonstrate the reliability and reproducibility of the operational second stage motor and the capability of the PQA motor to operate within model specification limits.* Successful accomplishment of these objectives was a requirement for the qualification of a 19-motor second-stage production lot.

* Model Specification S-133-1002-0-2A, Model Specification, Motor, Rocket SR19-AJ-1, Solid Propellant, Operational, dated 14 March 1973.

II. Test Objectives and Motor Description (cont)

B. MOTOR DESCRIPTION

Motor SN AA21517 was a standard Minuteman III production quality assurance motor modified to the operational configuration. The motor was fabricated in accordance with Drawing 382100-189AF. The motor incorporated a new material, Viton E 60 in the igniter assembly O-rings, that had not been previously flight tested.

The modification of the motor from the PQA static test configuration to the operational configuration consisted of replacing the static test igniter adapter and deleting the static test LITVC injector valves. The change of igniter adapters precludes measurement of igniter chamber internal pressure which is not a flight test data parameter. Operational P90 ACI units provided by the guidance and control associate contractor are utilized instead of the ASPC-supplied Moog injector units used in static tests. The two types of injector valves provide identical functional performance but are different in compatibility with the flight and static test control systems.

Propellant physical properties were as follows:

	Propellant ANB-3066 Lot 68 Vertical Mix		
	4969	4970	4971
Liquid-strand burning rate, in./sec*	0.3330	0.3295	0.3315
3KS-500 burning rate, in./sec	0.3290	0.3266	0.3276
Liquid density, gm/cc	1.7710	1.7715	1.7710
Initial tangent modulus, psi**	537	454	496
Maximum stress, psi* (77°F)	95.9	94.2	95.3
Elongation at maximum stress, % (77°F)	29.4	32.7	31.7
Shore hardness at end of cure	48	50	50

* 80°F at 700 psia
** 12-day cure at 115 $\pm$ 5°F

II. Test Objectives and Motor Description (cont)

C. NONDESTRUCTIVE TESTING

Motor SN AA21517 was radiographically examined in the Aerojet nondestructive test facility with a 10 MEV linear accelerator as the radiation source. The examination revealed no defects.

D. INSTRUMENTATION

The motor was instrumented with the standard flight test instrumentation, operational pressure transducers, and LITVC injector valve position transducers. The instrumentation was sufficient to evaluate motor performance although all operating characteristics normally associated with static testing cannot be evaluated. The items that cannot be evaluated are:

1. Igniter internal pressure: Instrument not installed.

2. Interstage pressure at ignition: Measurement and prediction based on chamber pressure are not possible because of slow sampling rate.

3. LITVC side force and injectant expulsion capability: Not evaluated because flight test requirements are different and significantly less than the specified PQA test duty cycle.

4. Roll Control Valve response time: Instrumentation not installed.

Test instrumentation was as follows:

II.D. Instrumentation (cont)

Parameter	Measurement Designation
Motor Chamber Pressure	OAF03
LITVC Manifold and Pressure	OAT02
Roll Control Gas Generator Pressure	OAG01
LITVC Pintle Position	DAU01 through 4
Roll Control Valve Actuation Commands	GGU06 and GGU07

III. TEST RESULTS

A. SUMMARY

Minuteman Special Test Missile 14W-1, with Aerojet Second Stage Motor AA21517 (PQA6-83), was successfully fired from Western Test Range Launch Facility 21 on 16 June 1977. Range zero time was approximately 1900 hr P.d.t. (0200:00.817) UTC. The second stage motor operated normally for a duration of 65.21 sec. Ballistic and control system performance were satisfactory. Flight event times were as follows:

Event	Time, sec
Missile Lift Off	0.0
Stage II LITVC/RC Discrete	60.094
I-II Discrete	61.745
Stage II Skirt Jettison	78.15
Stage III LITVC/RC Discrete	126.098
Shroud Eject Discrete	126.297
Stage II Motor Pc = 28 psia	126.922
II-III Discrete	127.037

III. Test Results (cont)

B. IGNITION AND STAGING

The motor ignited satisfactorily at an altitude of approximately 101,000 ft. Chamber pressure during ignition is compared with model specification limits in Figure 1. The estimated ignition delay of 108 millisec and maximum ignition pressure of 447 psia are very close to the average values of 108 millisec and 454 psia, respectively, for static firings. These values are estimated because of the normal occurrence of telemetered data dropout during motor ignition. Although internal igniter pressures were not obtained, the normal ignition implies satisfactory igniter performance.

C. BALLISTIC PERFORMANCE

Motor chamber pressure during action time was within model specification limits (Figure 2). Motor action time was 64.21 sec and the maximum chamber pressure was 537 psia at the estimated temperature of 70°F. The log book predicted values for these parameters, corrected to 70°F, are 65.19 sec and 538 psia, respectively. The action time of 65.21 sec at 70°F was within specification limits.

Vacuum thrust during action time, derived from flight guidance acceleration data, was well within model specification limits (Figure 3). On the basis of these data, the motor produced a delivered action time total impulse of 3,958,503 lb-sec. A 2400 lb-sec correction from the near-vacuum flight condition to vacuum condition resulted in an action time vacuum impulse of 3,960,093 lb-sec; the indicated vacuum specific impulse of 287.9 lbf-sec/lbm was 0.48 lbf-sec/lbm higher than the static test average. Vacuum thrust was within required limits (Figure 4); tailoff time from 41,000 lbf to 2000 lbf was 1.41 sec (corrected to 80°F). A plot of motor action time for a propellant temperature of 70°F is also shown in Figure 4.

III.C. Ballistic Performance (cont)

Derived ballistic data are tabulated in Figure 5, and motor performance values are compared with model specification requirements in Figure 6. Acceptance control data for average thrust, total impulse, thrust decay time, and motor action time are shown in Figures 7 and 8.

D. THRUST VECTOR CONTROL

1. <u>LITVC Subsystem</u>

LITVC subsystem performance was satisfactory throughout motor action time. The first indication of system pressurization was achieved 0.203 sec from the LITVC gas generator ignition discrete, the specified maximum delay time is 0.880 sec. System pressure of 500 psia was observed 0.468 sec after the discrete signal; specification limit is 0.95 sec maximum. System pressure was also maintained within specification limits after the pressurization transient (Figure 9). LITVC pressure regulation during the interval between system initiation and the I-III stage discrete (Figure 9) was normal and consistent with that of static test PQA motors.

Total injectant utilization during Stage II operation was 101.2 lb or 48% of the minimum expendable injectant weight. This utilization is not comparable with PQA test requirements since it represents the amount of injectant actually required for flight attitude control rather than the PQA duty cycle which is programmed to demonstrate total injectant expulsion capability. The amount used for normal attitude control was 40.6 lb or 19% of the expendable weight and is typical of past flight test experience. Injectant expended through the yaw injectors during the injectant dump cycle between 6.9 and 14.1 sec was 60.6 lb. A summary of injectant utilization is as follows:

III.D. Thrust Vector Control (cont)

Injector		Flow for Attitude Control, lb
1		8.8
2		0.2
3		12.2
4		19.4
	Total	40.6

Total Control, lb	40.6
Dump through yaw injectors, lb	60.6
Total injectant expended	101.2

LITVC system side force capabilities were not evaluated with PQA model specification requirements because the maximum side force and jet deflection required during the flight test were only approximately 820 lbf during the first 3 sec and 0.3 degrees thereafter. The values are considerably less than the 3800 lb side force and 2 degree jet deflection minimum capabilities demonstrated during the static PQA tests. LITVC performance is compared with specification limits in Figure 10.

2. Roll Control Subsystem

Roll control (RC) subsystem performance was satisfactory although the upper pressure specification limit was exceeded by 25 psi. Roll control moment capability was attained 219 millisec after the generator ignition discrete when the RC gas generator pressure increased to the required 1560 psia. The maximum pressure of 2425 psi occurred at 299 millisec and was 25 psi above the specified MEOP of 2400 psi. Gas generator pressure-vs-time curves are shown in Figure 11. Gas generator chamber pressure was within specification limits throughout the test. The minimum torque capabilities

III.D. Thrust Vector Control (cont)

were as follows: 432 ft-lb from 0.7 to 7.7 sec after the gas generator discrete time, 148 ft-lb to 15.7 sec, and 95 ft-lb at the end of Stage II action time.

As previously reported, the roll control gas generator exhibited the overpressure characteristics similar to that observed in Motors 52PQA6-80, 52PQA6-81/STM 13W, STM 11W, and STM 12W. The pressure-time histories of these five motors are presented in Figure 12. The generators in question were all from the same production lot (505R) with the exception of the unit used on STM-14W which was from lot 507R. The anomalies are attributed to incomplete compaction of the generator ignition booster pads. Corrective actions have been taken to ensure proper compaction.

Roll control valve response times could not be evaluated with respect to model specification requirements because of the lack of instrumentation. However, performance of the valve is considered satisfactory based on adequate control of the missile in the roll attitude during motor operation. Only minimal roll control utilization, 7 clockwise and 16 counterclockwise commands, was required.

Roll control performance is summarized and compared with PQA model specification requirements in Figure 10.

E. INSTRUMENTATION PERFORMANCE

Instrumentation and telemetry system performance was satisfactory and provided adequate data for the evaluation of motor performance.

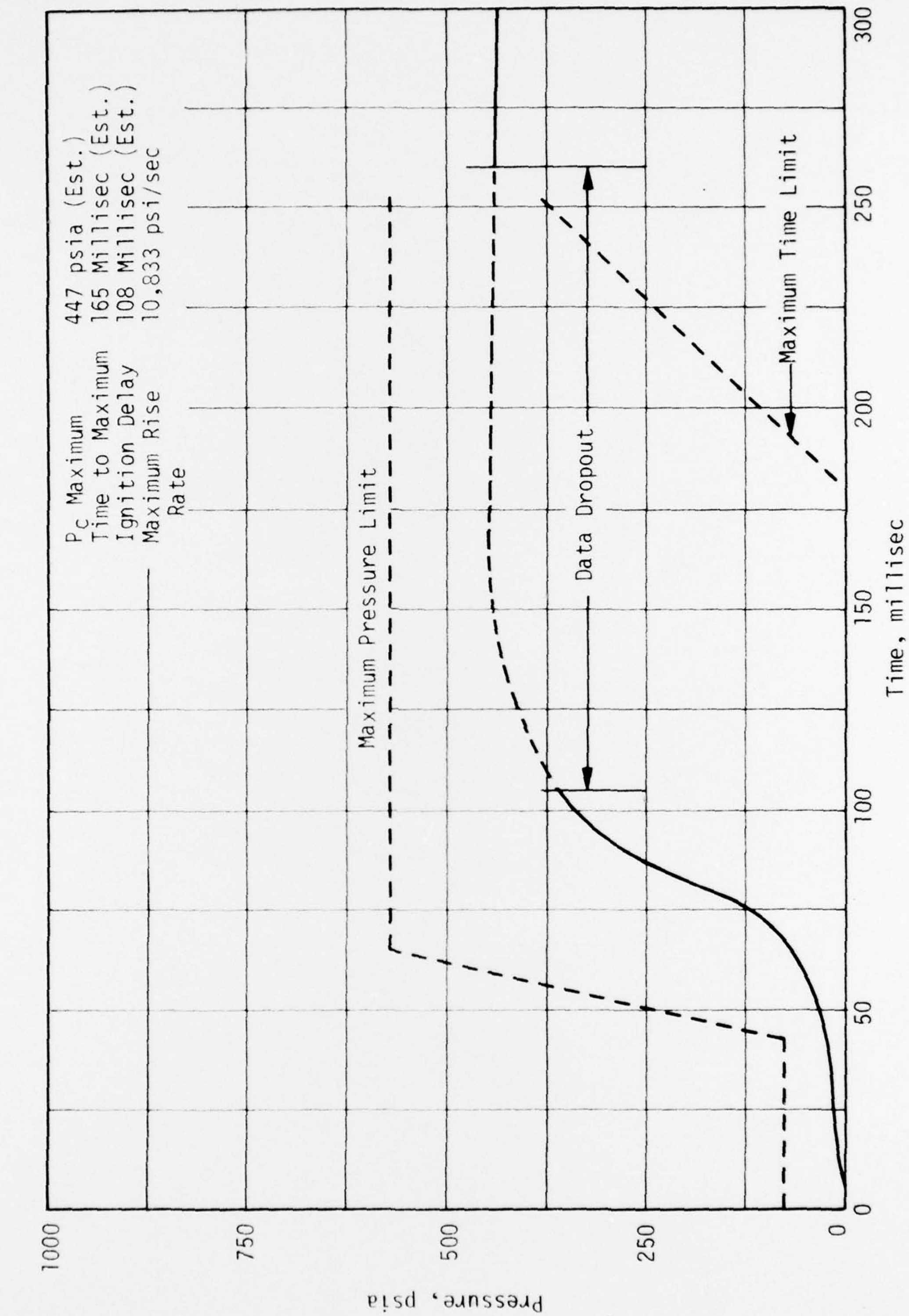
F. MOTOR RELIABILITY

Posttest reliability data are presented in Figure 13.

IV. CONCLUSIONS AND RECOMMENDATIONS

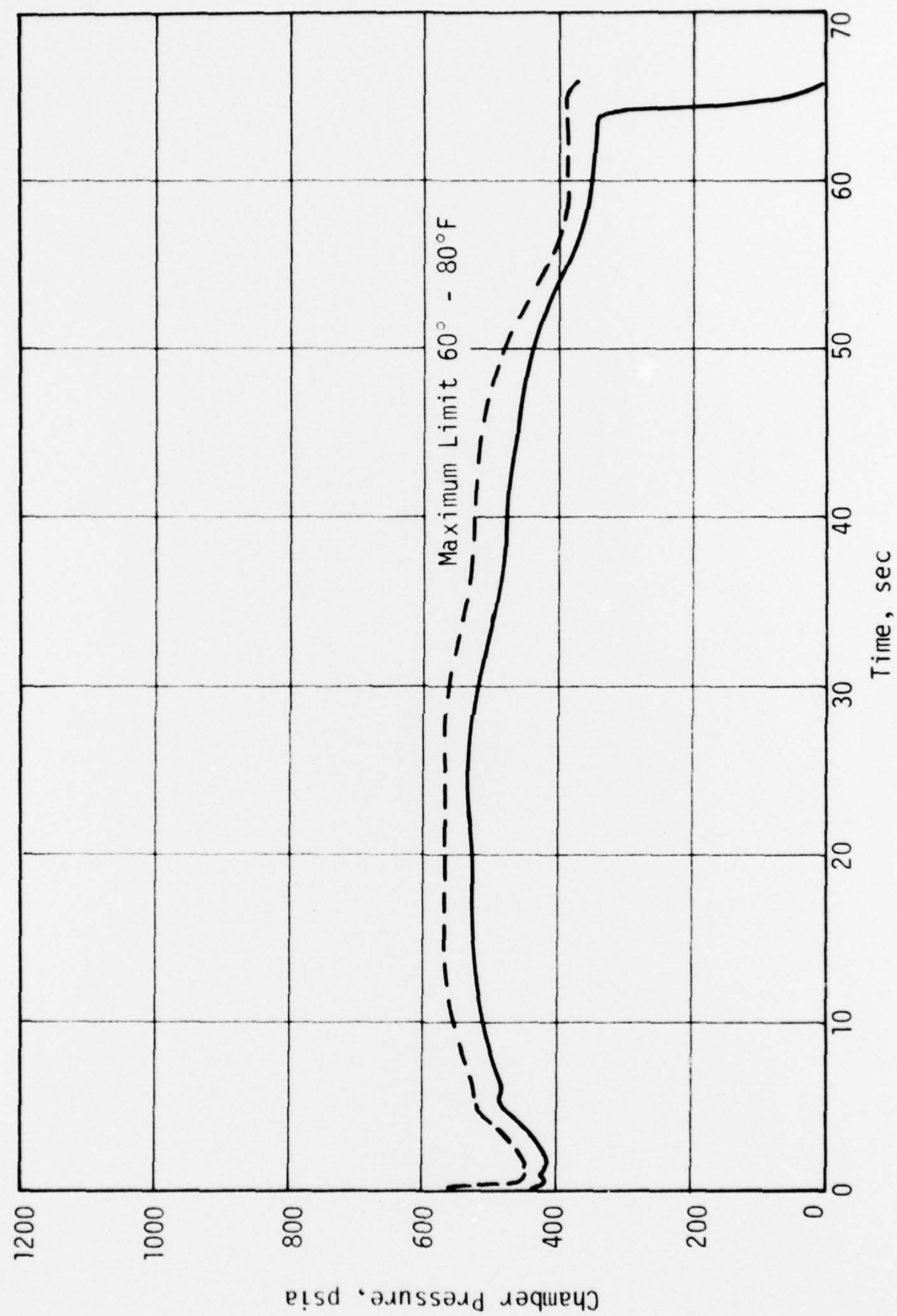
Overall performance of the second stage motor was satisfactory. The motor operated for an action time of 65.2 sec; all available performance parameters were within specification limits. Performance of the LITVC and RC subsystems were satisfactory.

The flight test of Motor STM-14W-1 (52PQA6-83) was the qualification test for Production Motors Air Force SN AA21511 through 21530. Aerojet recommends that Motor 52PQA6-83 used in STM-14W-1 be accepted as a successful Wing VI Quality Assurance Motor.



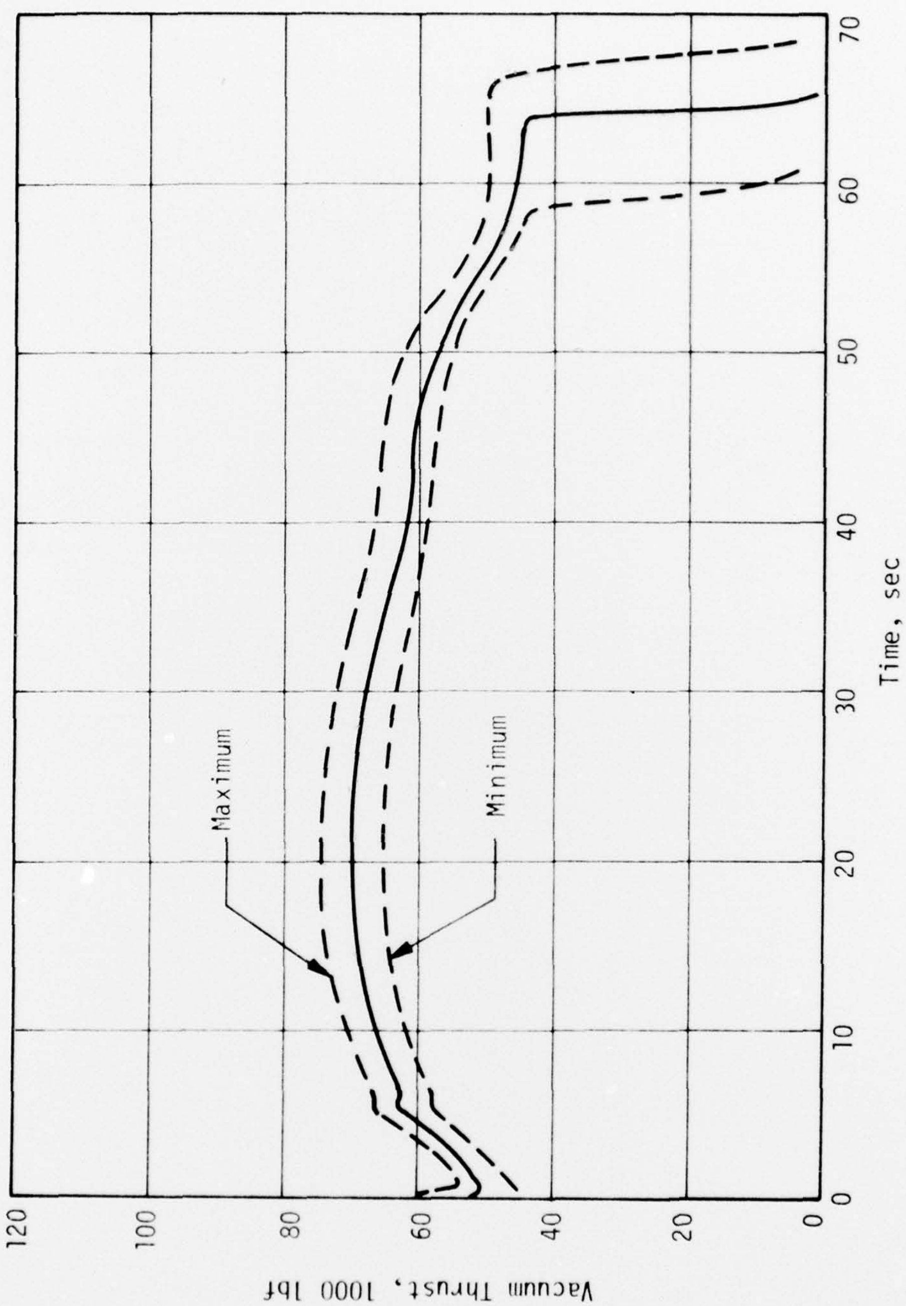
Chamber Pressure During Ignition, 60 to 80°F

Figure 1



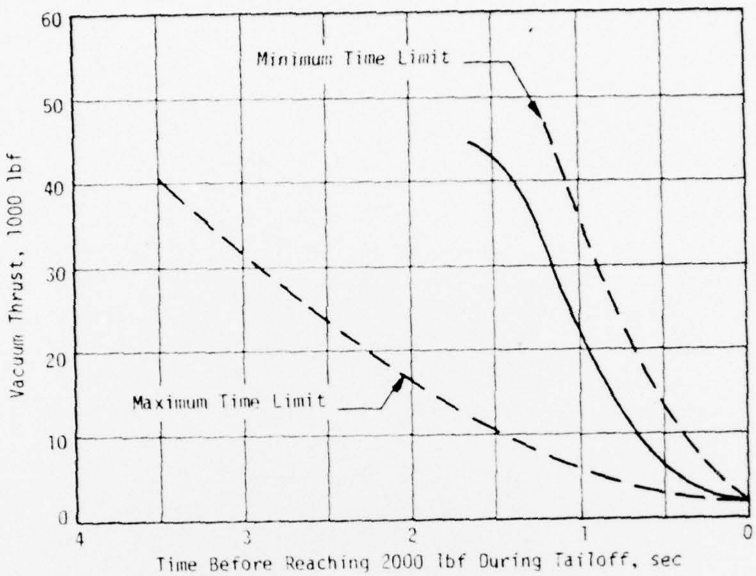
Chamber Pressure vs Time

Figure 2

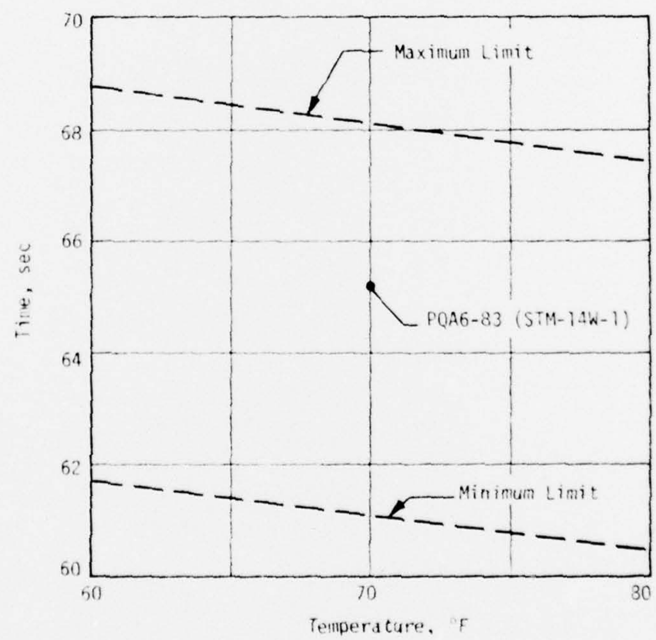


Vacuum Thrust vs Time, 60 to 70°F

Figure 3



Vacuum Instantaneous Thrust During Tailoff



Action Time vs Propellant Grain Temperature at 70°F

Thrust and Temperature Data, End of Motor Action Time

Figure 4

Motor Data	Prefire
Total motor weight, lb	15,530.3
Total propellant weight, lb	13,758.6
Total inert weight, lb (including 265 lb Freon)	1,771.7
Center-of-gravity, in.	
X axis	116.154
Y axis	100.035
Z axis	99.989
System mass fraction	0.886
Nozzle throat area, sq in.	72.90
Nozzle exit cone area, sq in.	1807.3
Nozzle expansion ratio	24.79

Ballistic Data	As Fired (70°F)	80°F
Ignition delay, millisec	108	
Max ignition pressure, psia	447	
Max interstage pressure, psia	Not available	
Action time, sec	65.21	64.56
Max chamber pressure, psia	529	534
Av chamber pressure, psia	456	461
Max vacuum thrust, lbf	69,680	70,380
Av vacuum thrust, lbf	60,736	61,346
Action time vacuum impulse, lbf-sec	396,093	
Propellant vacuum specific impulse, lbf-sec/lbm	287.88	
$P_{sn}dt$, psia-sec	29,761	

Derived Ballistic Data

Figure 5

	Motor 52PQA6-83	Model Specification Limits
Motor action time at firing temperature	65.2	Figure 7*
Motor action time at 80°F, sec	64.6	Figure 7*
Thrust tailoff decay time, sec	1.41 (80°F)	1.10 to 3.50****
Maximum chamber pressure at firing temperature, psia	533	Figure 6*
Maximum chamber pressure at 80°F, psia	538	Figure 6*
Action-time impulse (60 to 80°F), lbf-sec**	3,958,503	3,907,000 (min)
Maximum thrust at firing temperature, lbf	69,680	Figure 1*
Maximum thrust at 80°F, lbf**	70,380	Figure 2*
Average thrust (60 to 70°F), lbf**	60,700	56,000 to 65,700
Average thrust at 80°F, lbf	61,346	56,000 to 66,300
Motor ignition delay (60 to 80°F), millisec	108	250 (max)
Predicted maximum interage pressure, psia	Not available	75 (max)
Gross motor weight, lb	15,530.3	15,626 (max)
Total propellant weight, lb	13,756.6	13,680 (min)
Weight of loaded Freon, lb	265	255 to 265
System mass fraction	0.886	0.884 (min)
Prefire center of gravity, in.***	55.364	53.2 to 56.8
Motor/nozzle throat alignment	0.005	0.046 (max)
Angular relationship, degrees	0.001	0.073 (max)

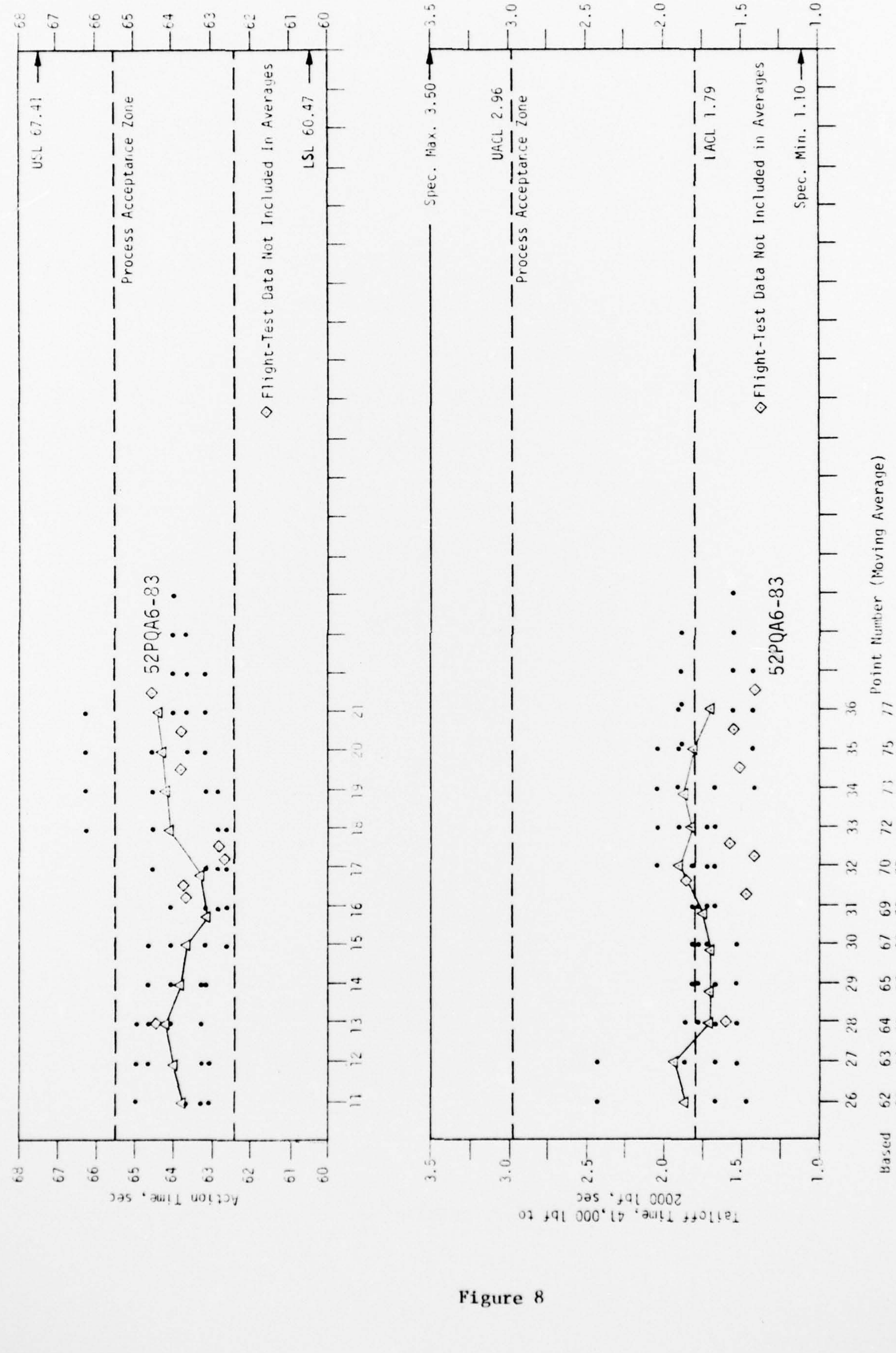
* Limits shown in curve form in specification.
** Vacuum conditions; excludes axial thrust augmentation.
*** Measured aft of forward skirt.
**** SCN 22

Comparison of Motor Performance with Model Specification Limits

Figure 6

Acceptance Control Data, Average Thrust and Total Impulse

Figure 7



Acceptance Control Data, Motor Action Time and Thrust Decay Time During Motor Tailoff

Figure 8

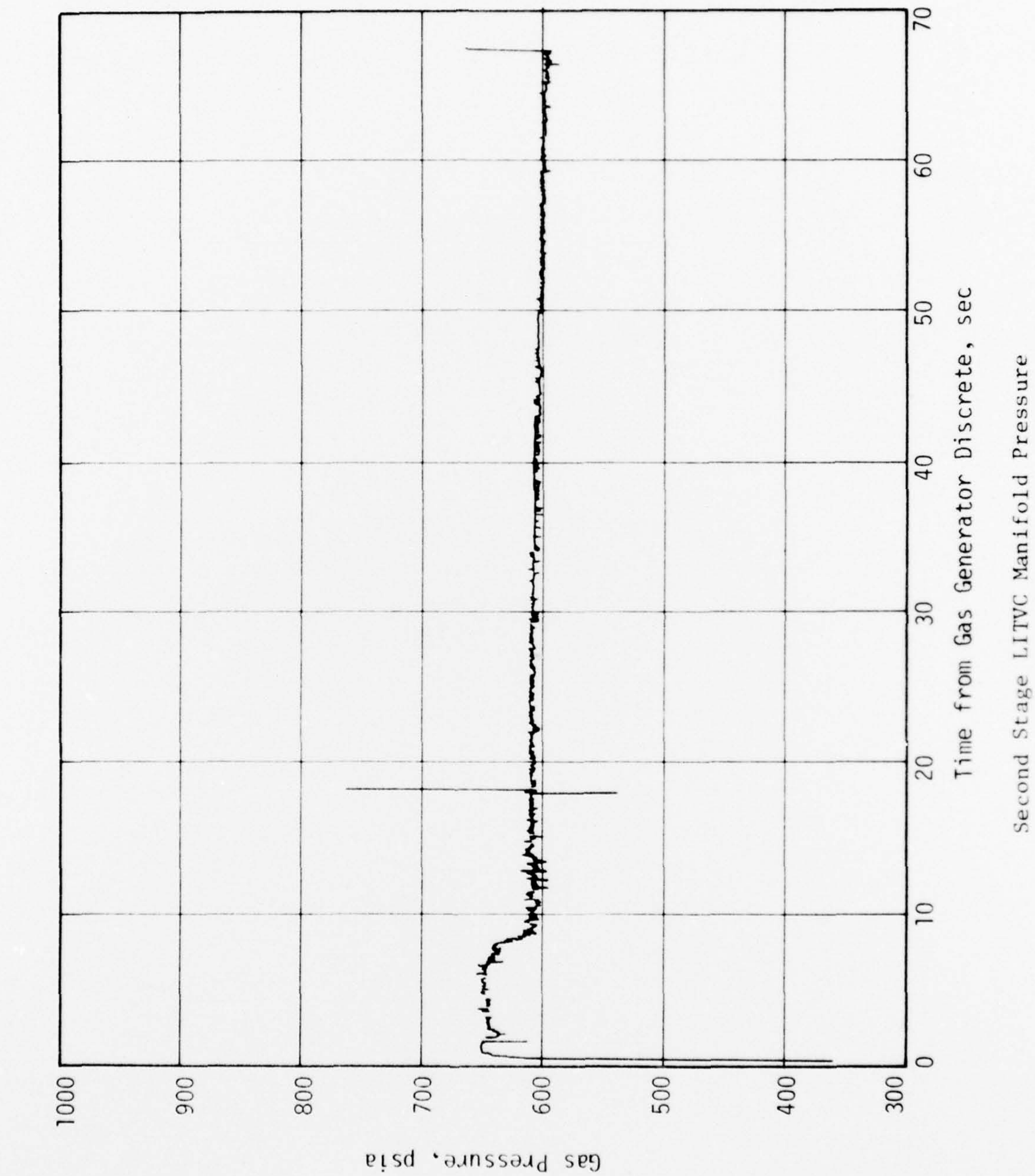

Second Stage LITVC Manifold Pressure
Time from Gas Generator Discrete, sec
Gas Pressure, psia
0
10
20
30
40
50
60
70
1000
900
800
700
600
500
400
300

Figure 9

	Measured or Calculated	Model Specification Requirements
Side Force Impulse		
Measured side force at 2.7 sec, lb	NA	3800 (min)
Measured jet deflection at 52.7 sec, degree*	NA	2 (min)
Pressurization Time, sec		
Time until first indication of pressure	0.203	0.880 (max)
Time until 500 psia in last injector cavity	0.453	0.950 (max)
Time until 1560 psia in roll control gas generator	0.219	0.700 (max)
Roll Control Response, sec		
Null to 90%	NA	0.035 (max)
Hardover to 10%	NA	0.050 (max)
Hardover to 90%	NA	0.050 (max)
Pressure, psia		
Maximum injectant pressure at 0 lb/sec flow rate	651	713 (max)
Minimum injectant pressure	588	560 (min)
Minimum injector pressure at full flow rate	NA	425 (min)
Maximum roll control gas generator pressure	2425	2400 (MEOP)
Roll control gas generator pressure at end of motor action time	345	255 (min)
Torque, ft-lb		
Torque capability at 7.7 sec**	432	350 (min)
Torque capability at 15.7 sec**	148	120 (min)
Torque capability at end of action time	95	70 (min)

* Measured from motor ignition
** Measured from gas generator ignition

LITVC and RC Performance Summary

Figure 10

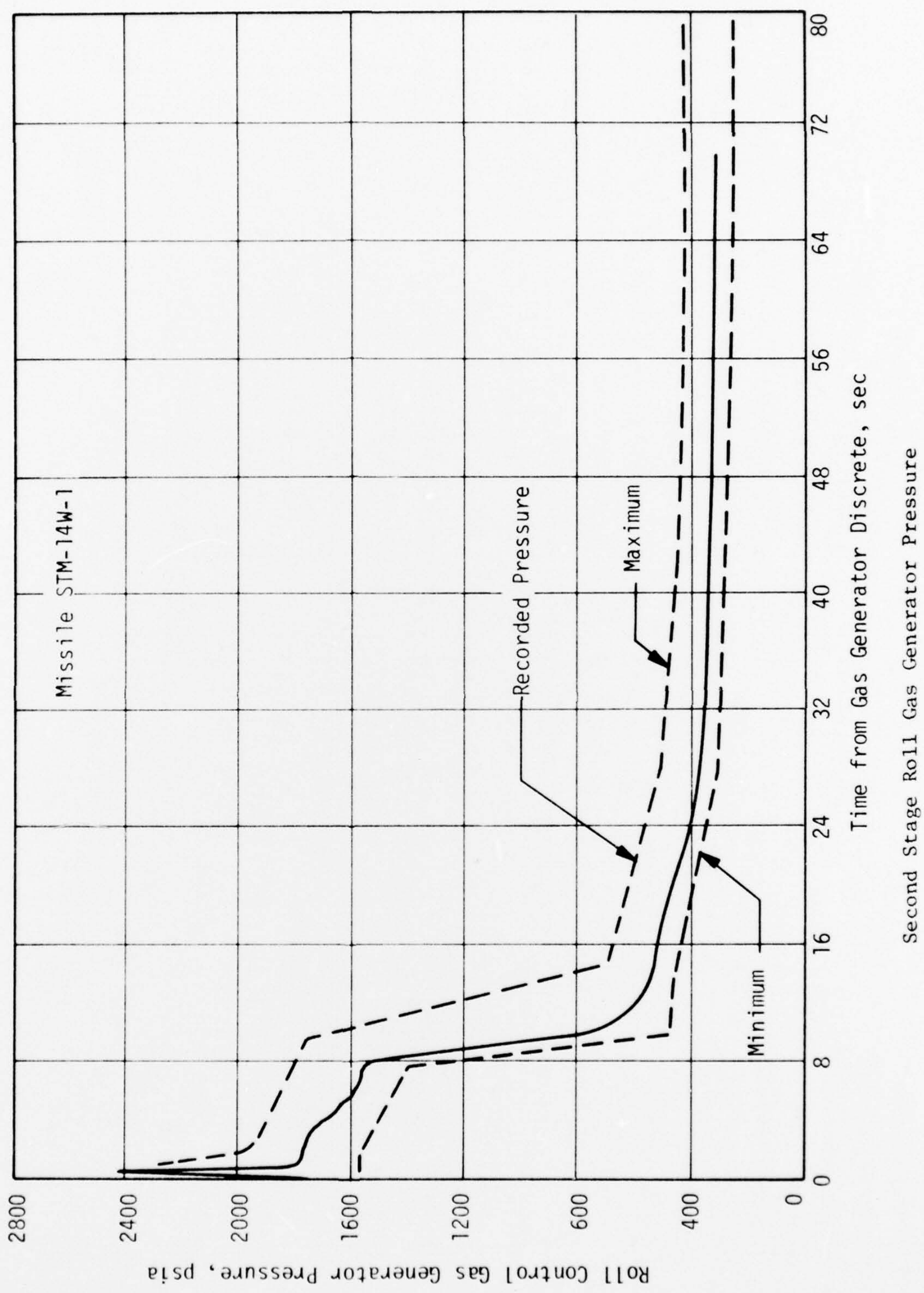
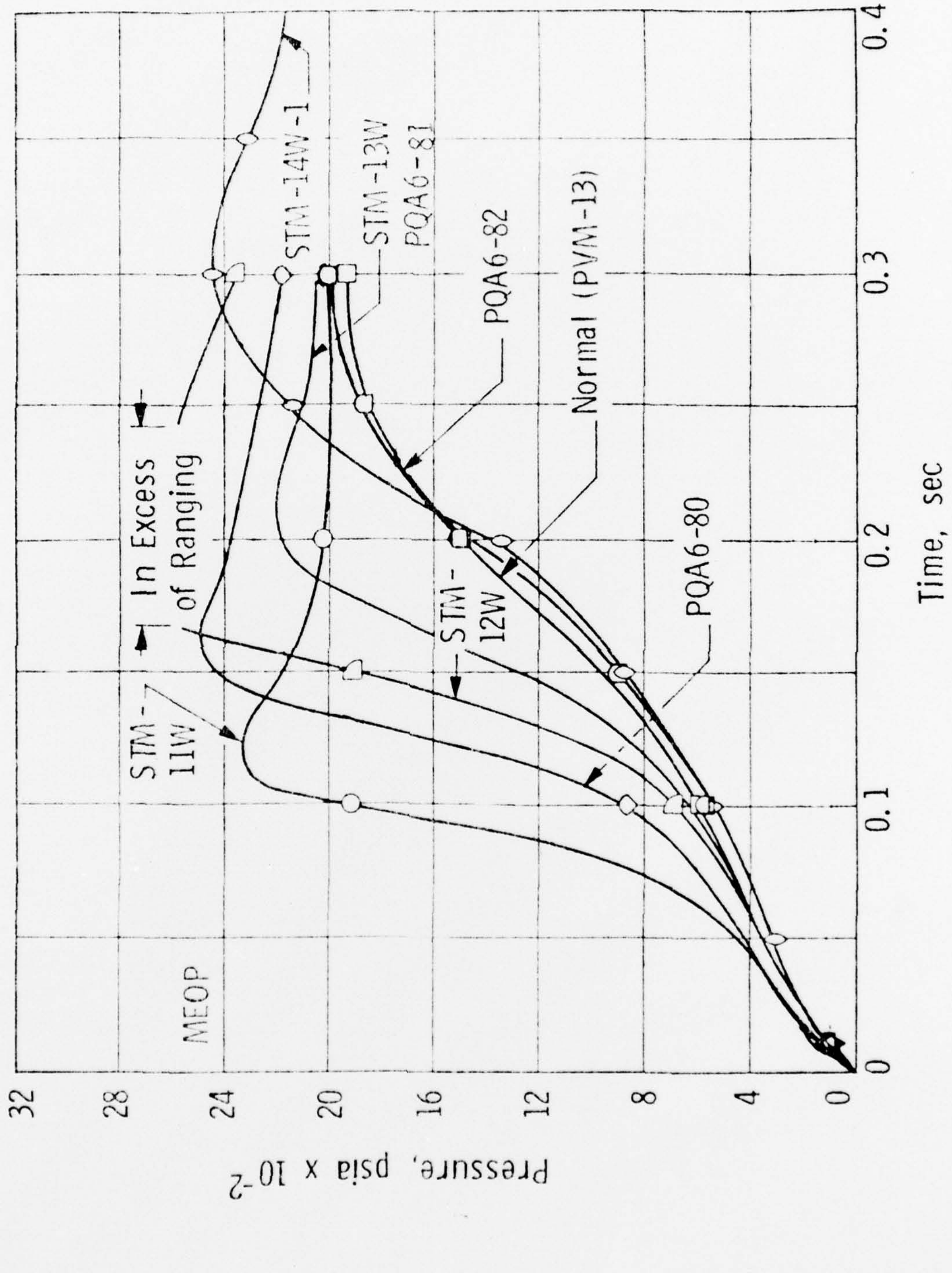

Missile STM-14W-1
Recorded Pressure
Maximum
Minimum
Roll Control Gas Generator Pressure, psia
2800
2400
2000
1600
1200
600
400
0
Time from Gas Generator Discrete, sec
0
8
16
24
32
40
48
56
64
72
80
Second Stage Roll Gas Generator Pressure

Figure 11



Comparison of Roll Control Gas Generator Ignition Transients

Figure 12

AGCS 1920 7 (S) (REV 6 71)

WING VI POST-TEST RELIABILITY REPORT FORM

Test No.	(200)	Name of Contractor	Aerojet Solid Propulsion Company
Test Date	(202) (MO-DAY-YR) 06-16-77	Date form completed by Cont'r.	(MO-DAY-YR) 08-04-77
Motor SN	(205) (FTM-5747, STM-14W-1) 52 PQA6-83, AA21517	Signature of Contractor	L P Trinberger
Motor Type	(207) Wing VI Operational		Bess Inyunshi
Applicable Specs.	(208) S-133-1002-0-2		

Chamber Serial Number 7024031

MOTOR TEST DATA

If any of the following parameters are outside the applicable model specification limits, or exceeds predicted performance limits, indicate fact by asterisk in column before parameter.

	(240) Action Time Impulse, lbf. sec. (I_a)	3,960,093
	(241) Average Thrust, lbf (F)	61,346
	(242) Thrust curve within limits	YES [XX] NO [ ]
	(243) Max. Thrust, lbf (F_{max})	70,380
	(244) Specific Impulse, lbf sec/lbm (I_s)	287.88
	(245) Trajectory Action Time, sec (t_a)	64.56
	(246) Average Chamber Pressure, Psia (P_{sn})	461
	(247) Max. Chamber Pressure, (Psia)	534
(1)	(248) Predicted Interstage Pressure, (Psia)	
	(249) Ignition Delay, sec (t_i)	.108
	(250) Ignition Peak Pressure Psia (P_i)	447
	(251) Useful Propellant Weight, lbm (W_{pa})	13,753.6
	(252) Motor Weight, (Gross) lbm (W_m)	15,530.3
	(253) System Mass Fraction (λ_s)	0.886
	(254) Grain Temperature, °F	70
	(255) Thrust Tailoff Decay Time, sec	1.41

TVC

(1)	(260) Max Side Thrust, lbf	
	(261) Injectant Pressurization Time, sec	0.468
(1)	(262) Thrust-Vector Angle Within Limits	Yes [ ] No [ ]

ROLL CONTROL

	(263) Max Gas Generator Pressure, psia	2425
	(264) Pressurization Time, sec	0.219
	(265) Roll Control Moment Within Limits	Yes [X] No [ ]

(1) (266) Max Response Time, sec

O-HARDOVER	HARDOVER-O	HARDOVER-HARDOVER

Remarks about Performance: Motor flight test data converted to 80°F, based on estimated grain temperature of 70°F.

(1) Not available on flight tests.

TEST RESULT CLASSIFICATION

Legend: S, Success, F, Failure, PE, Pretest Exclusion, AE, Posttest Exclusion

CONFIGURATION	WING VI QUAL	WING VI OPER	WING VI OTHER	REMARKS
(270) SUBSYSTEM A		S		Subsystem classifications are based on satisfactory
(271) SUBSYSTEM B		S		missile performance during second-stage operation.
(272) SUBSYSTEM C		S		
(273) SUBSYSTEM D		S		
(274) SUBSYSTEM E		S		
(275) SUBSYSTEM F		S		

Final Reliability Report Form

Figure 13